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Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

A 2.45 GHz Novel Electrically Small Planar Dipole Antenna

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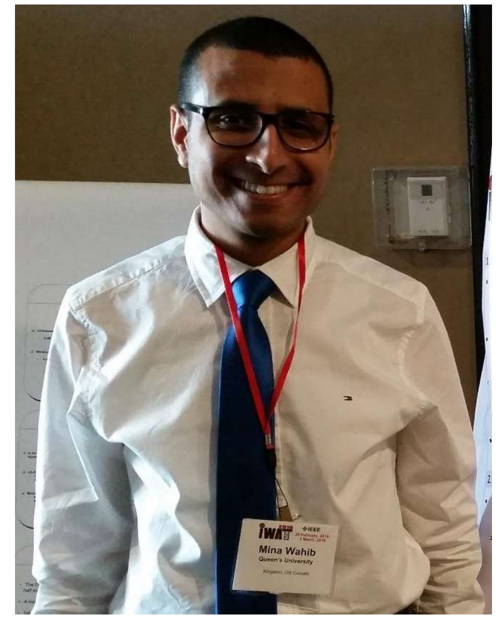
Abstract

Abstract— In this paper a novel electrically small planar dipole antenna operating at 2.45 GHz is proposed. This antenna exhibits small dimensions of 11.2 X 5.1 X 1.575 mm^3 (0.09 X 0.04 X 0.01 λ_0^3) which is considered to be one of the smallest ever reported footprints at this operating frequency. It has a simulated realized gain of 1.17 dBi along with an estimated efficiency of 87.4%. Due to the fact that ESAs are not self-resonant by nature, an impedance matching network has to be utilized to tune the antenna to resonate at the desired operating frequency. Three different matching approaches are studied in this paper. Finally, the antenna is modelled using the infinitesimal dipole model.

Keywords— Electrically Small Antennas (ESAs); Matching; Miniaturization; End-loading; Planar Antennas

Biography

Mr. Wahib graduated from the German University in Cairo in July 2014 with a B.A.Sc. in electrical engineering with highest honors. During his bachelor, he was awarded a DAAD exchange scholarship to spend six months at the Technical University of Darmstadt in Germany where he worked in the field of chipless RFID. He developed a new technique for the identification of UWB chipless RFID tags. He also showed the possibility of using such tags for temperature sensing applications. Soon after Mr. Wahib finished his bachelor he travelled to Canada to pursue his M.A.Sc. at Queen's University, where he is currently studying. He is working on the development of LTCC filters for military applications. Moreover, he is working as a research assistant at the Royal Military College of Canada, where he is developing electrically small antennas for practical applications.



Introduction

- Antennas are essential components for most wearable gadgets (For Example: Smart watches).
- A $\lambda/2$ resonating antenna can not be easily integrated within a small area.
- ESAs are good candidates for such an application. However they are non-resonant and have low efficiency.
- Efficient matching of an ESA could enhance its efficiency and gain.

Introduction

Design Equation

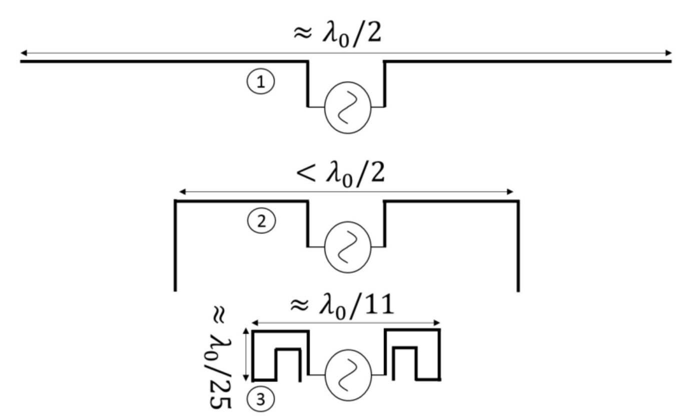
The input impedance of an **ESA**

$$Z_{in} = \underbrace{(R_{rad.} + R_{loss})}_{R_{in}} + \underbrace{j(X_{ind.} + X_{cap.})}_{jX_{in}}\ \Omega$$

Introduction

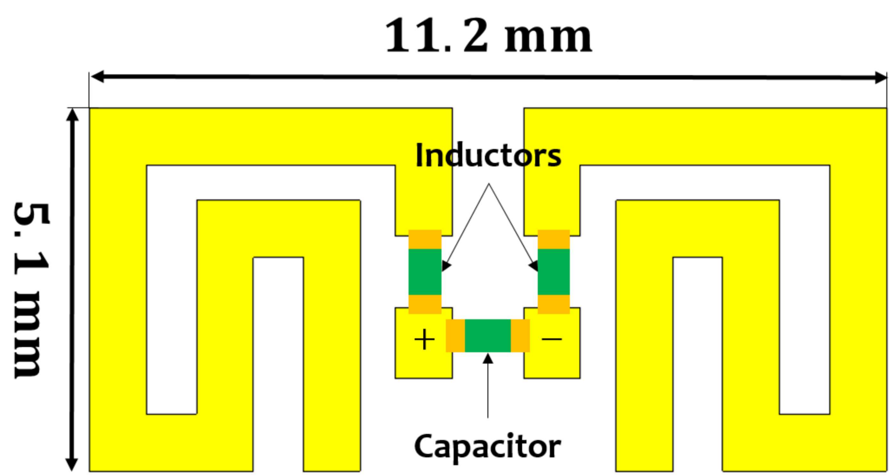
Antenna Design

Meandering is an effective miniaturization technique (**ka=0.31**)



Approach I
Open-ended

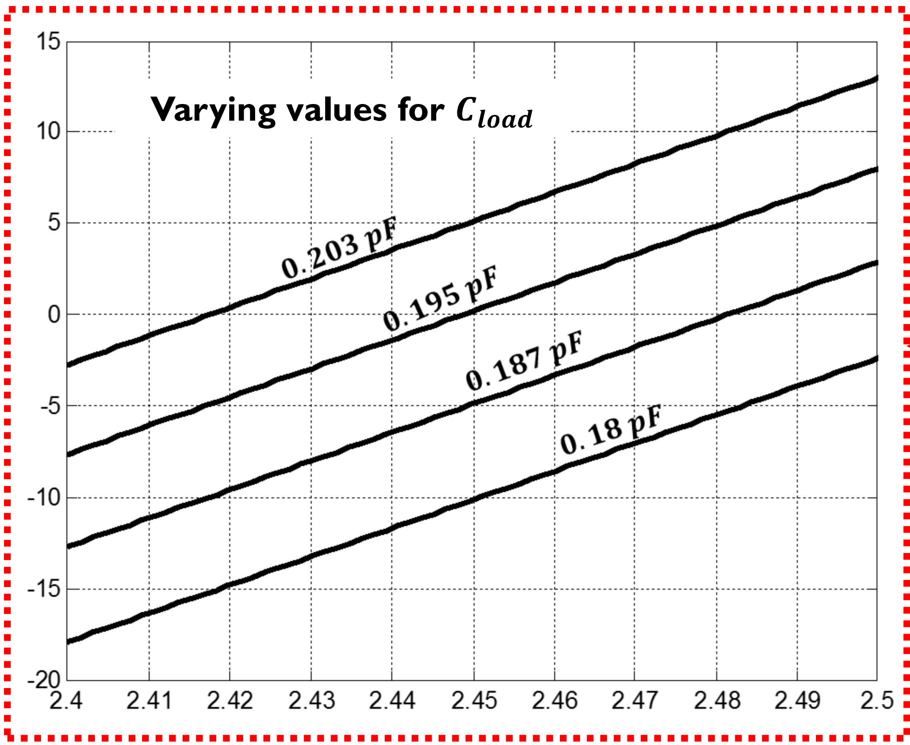
- A low-pass differential LC matching network is used to compensate for the **negative imaginary input impedance ($-j248\ \Omega$)** and transform the **small resistive ($1.98\ \Omega$)** impedance to $50\ \Omega$.

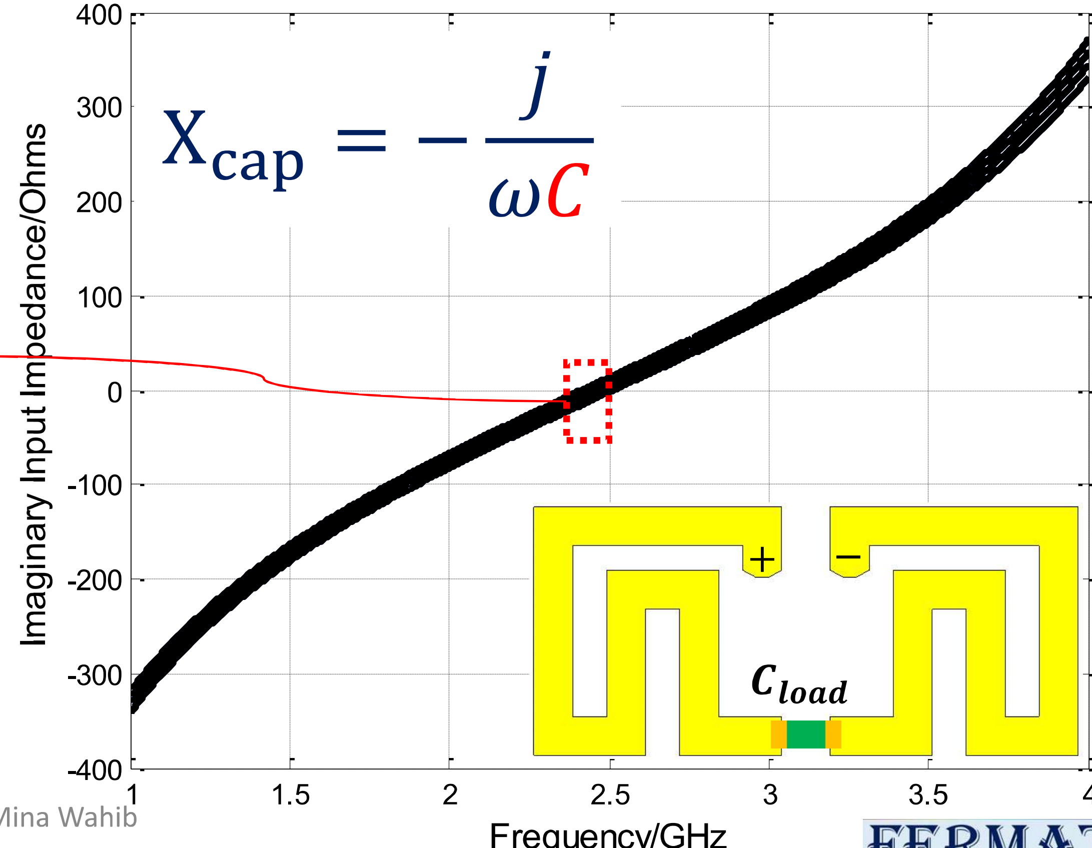


η_{rad}	87.4%
Gain	1.17 dBi
L_{series}	7.6 nH
C_{shunt}	3.8 pF

Approach 2

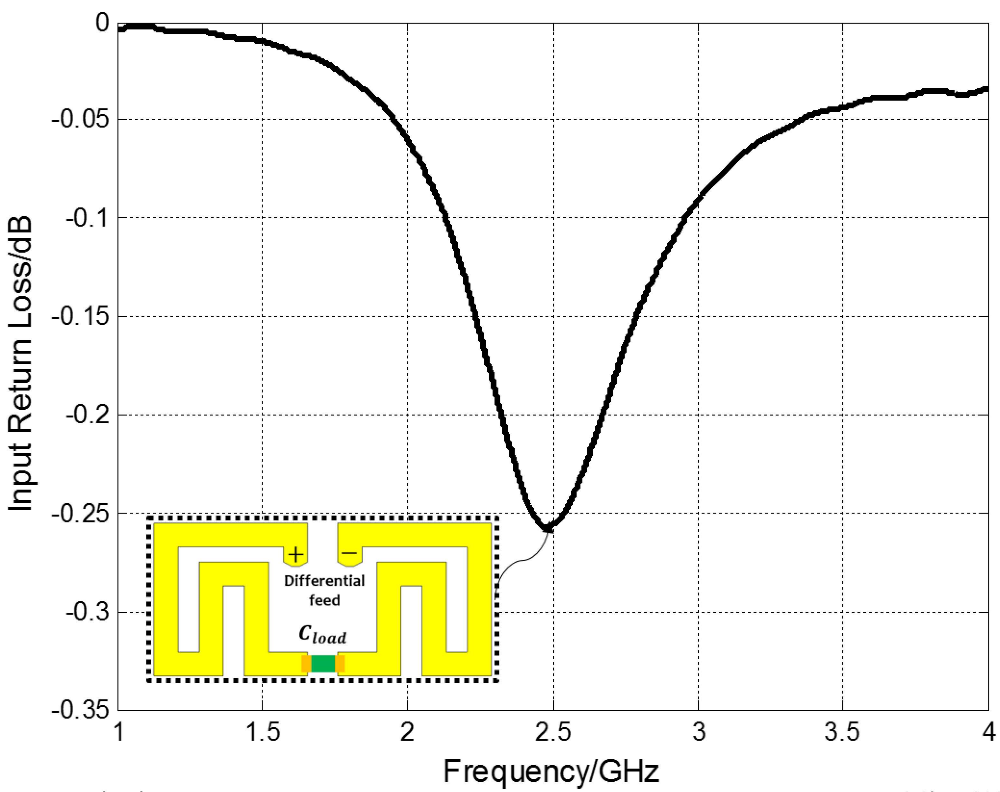
Capacitively Loaded





Approach 2

Capacitively Loaded

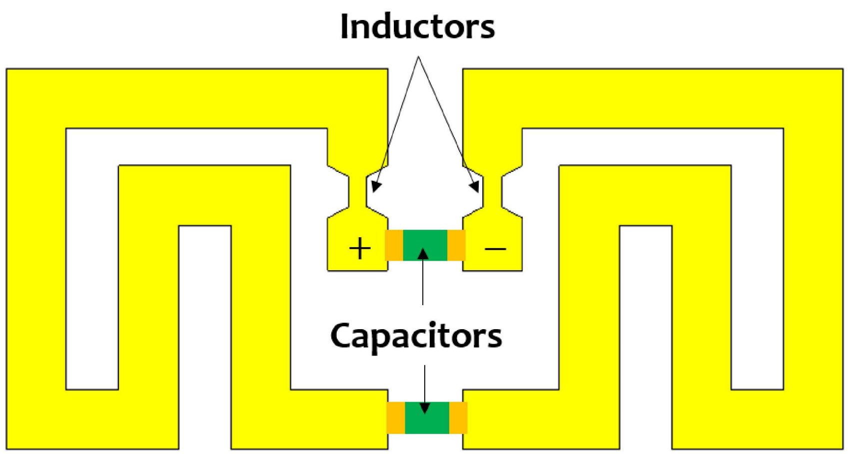


Resonating, BUT Not yet Matched!

Because of the very small value for the resistive component.

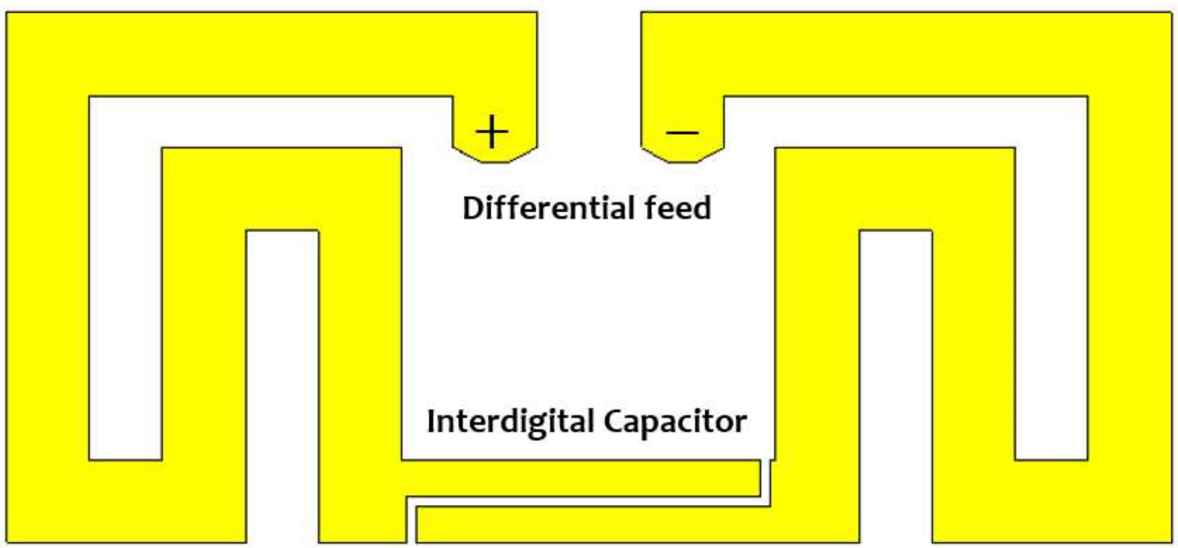
Approach 2
Capacitively Loaded

- **End-loading capacitor** increases the capacitance in the antenna structure and thus causes resonance. A simple differential matching network is then used to match the small resistive component to $50\ \Omega$.



η_{rad}	**37.5%**
C_{shunt}	**5.4 pF**
C_{load}	**0.19 pF**

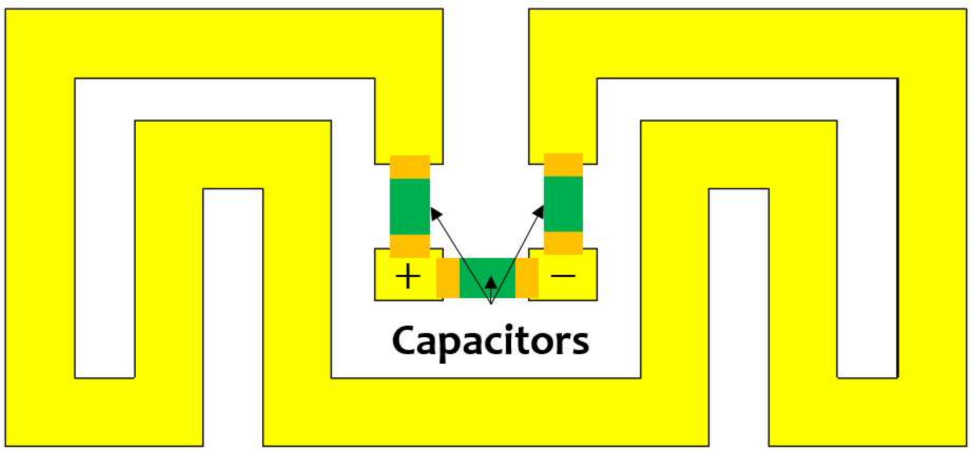
Approach 2
Capacitively Loaded



- An end-loading **interdigital capacitor** can be used instead of the lumped element end-loading capacitor to cause the antenna to resonate. The antenna will still have quite similar performance if compared to the previous case.

Approach 3
Inductively Loaded

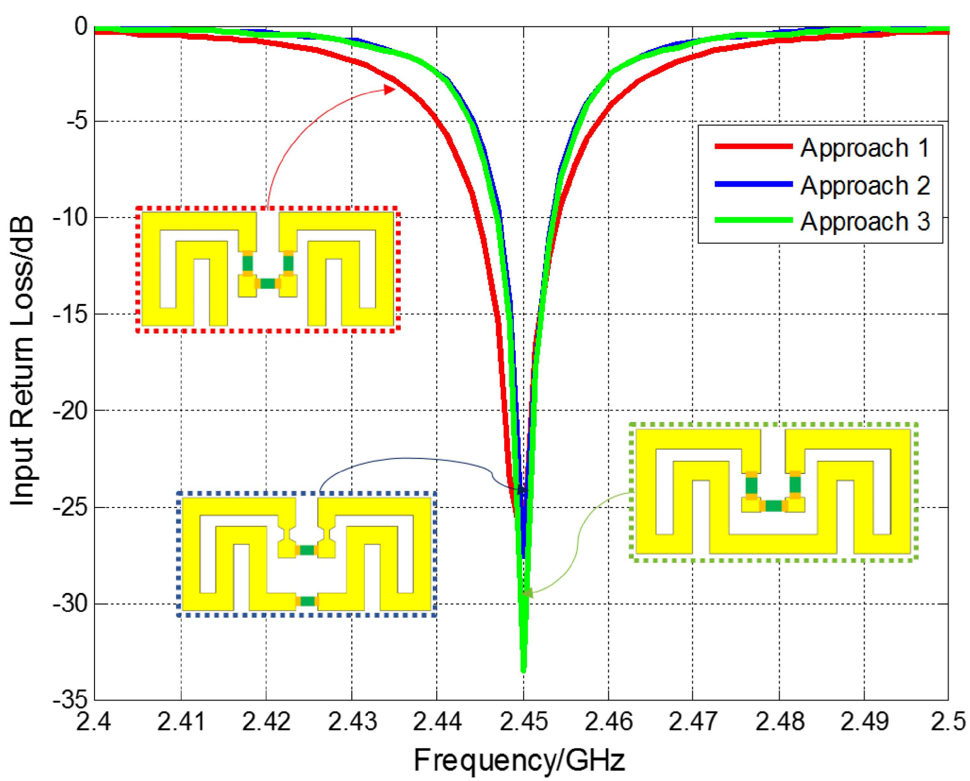
- **An all-C matching network** is used to match a purely inductive input impedance antenna ($j318\ \Omega$).

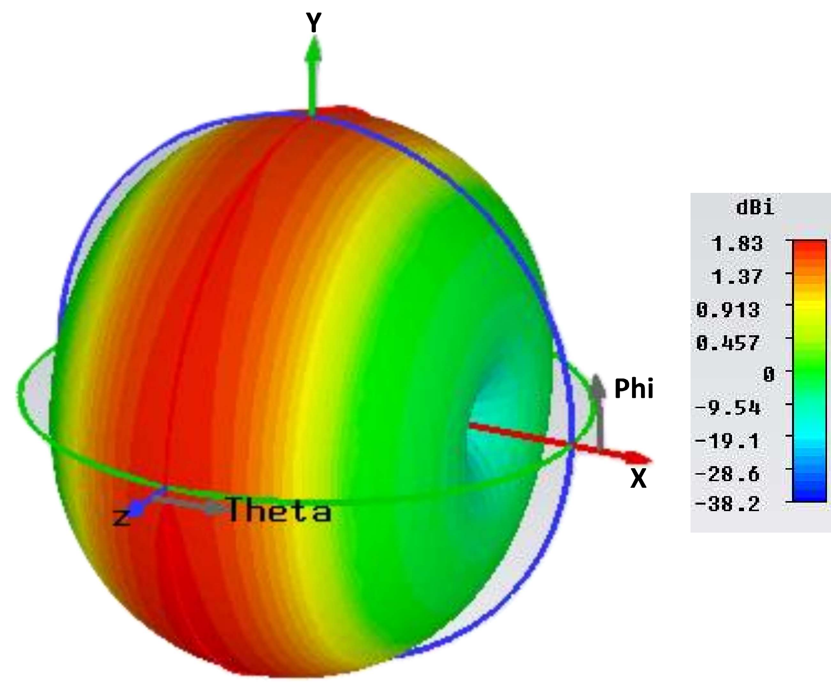


η_{rad}	**36.5%**
C_{series}	**0.44 pF**
C_{shunt}	**4.14 pF**

Simulations

S-Parameters and Radiation

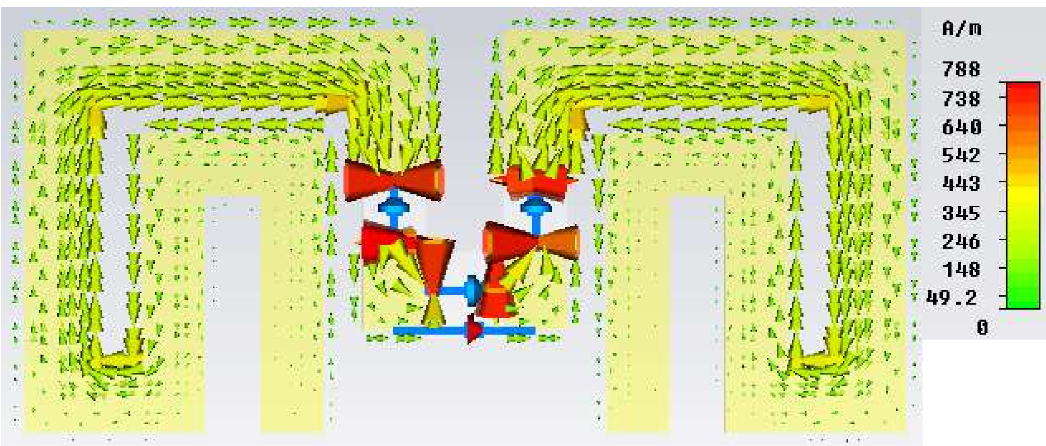


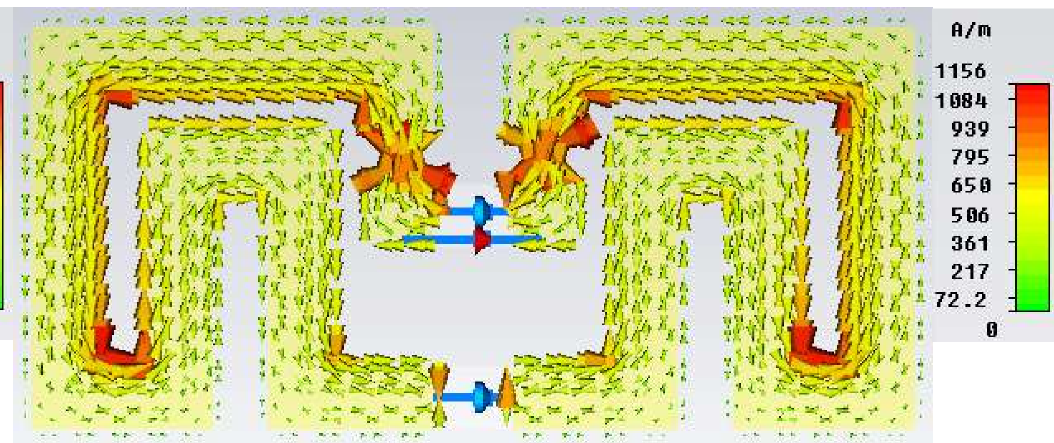


3D Directivity Pattern

Simulations

Surface Current Distribution





Approach 1

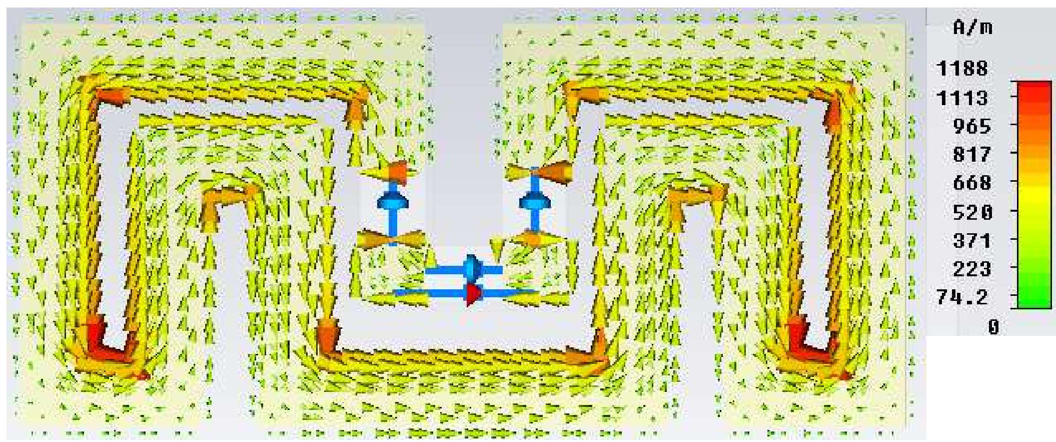
788 A/m

Approach 2

1156 A/m

Simulations

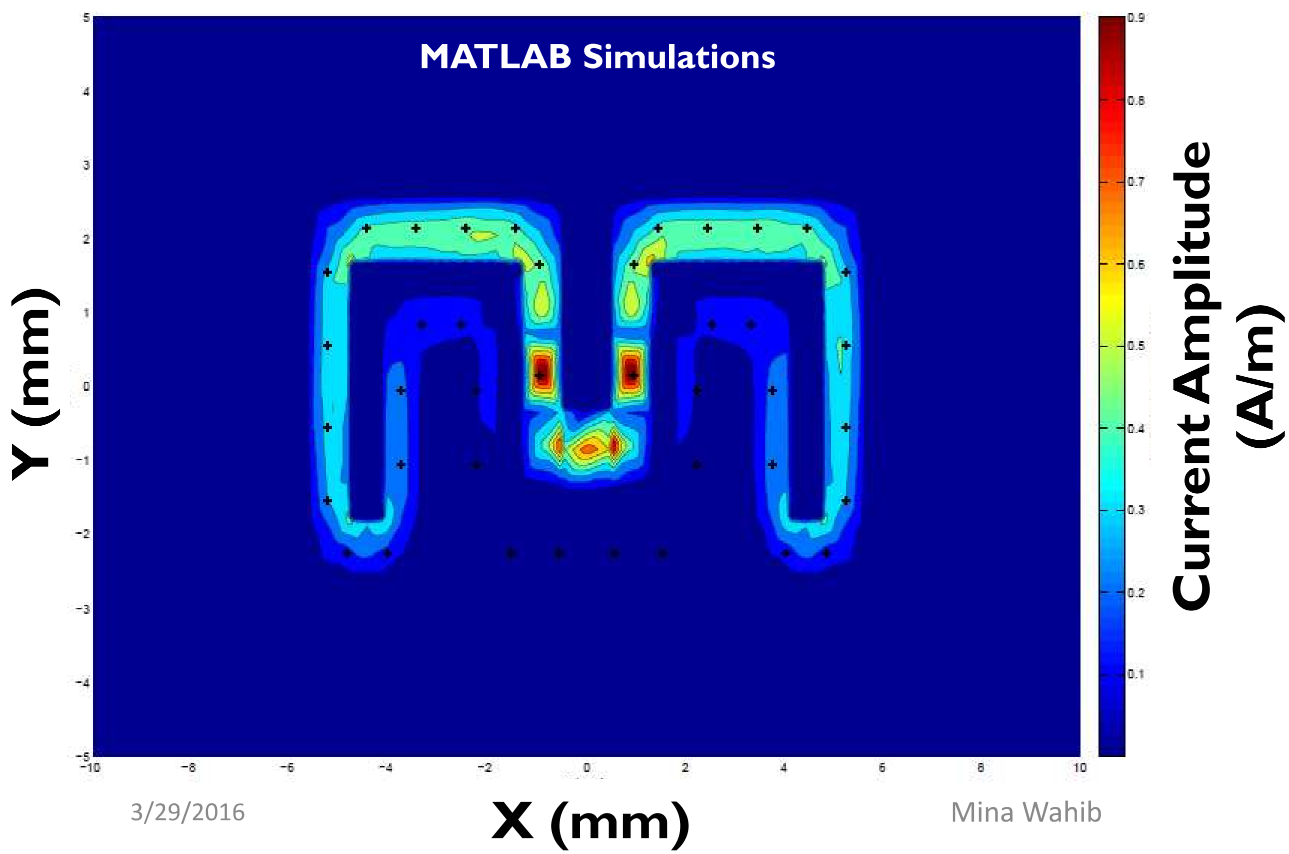
Surface Current Distribution



Approach 3

1188 A/m

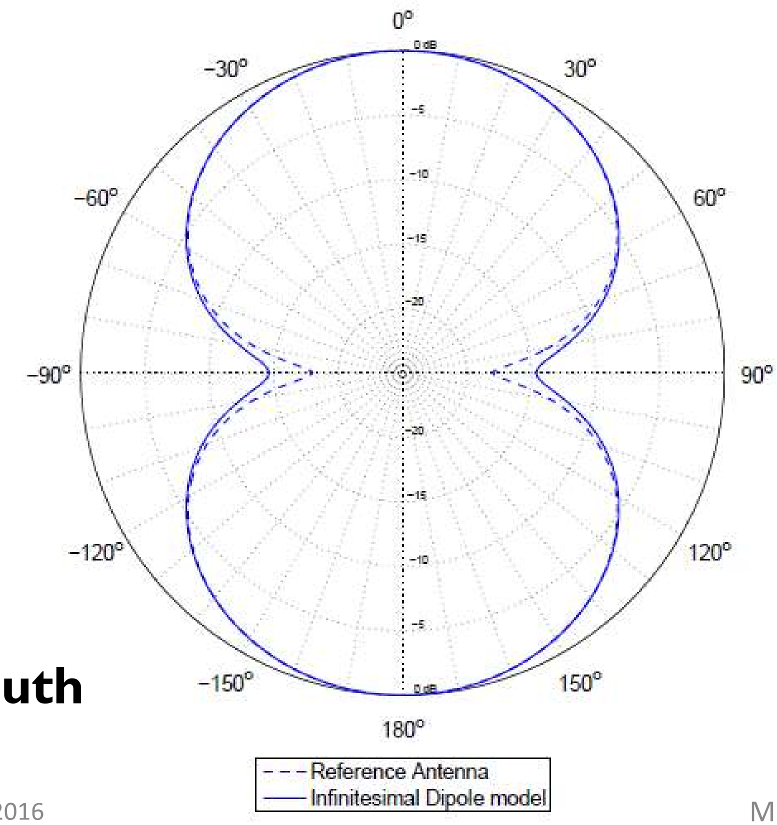
Infinitesimal Dipole Modelling *(IDM)*



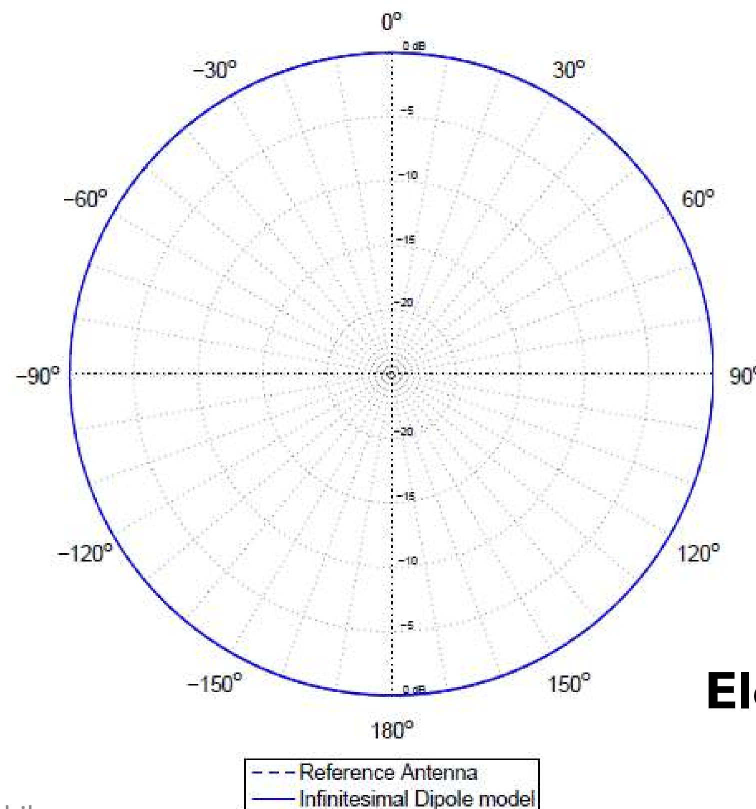
- IDM is often used as an easy way to model complex antenna structures.
- Approach 1 antenna was modelled by **40** IDs.

Infinitesimal Dipole Modelling *(IDM)*

Reference Antenna : CST Simulated
IDM : Calculations done over MATLAB

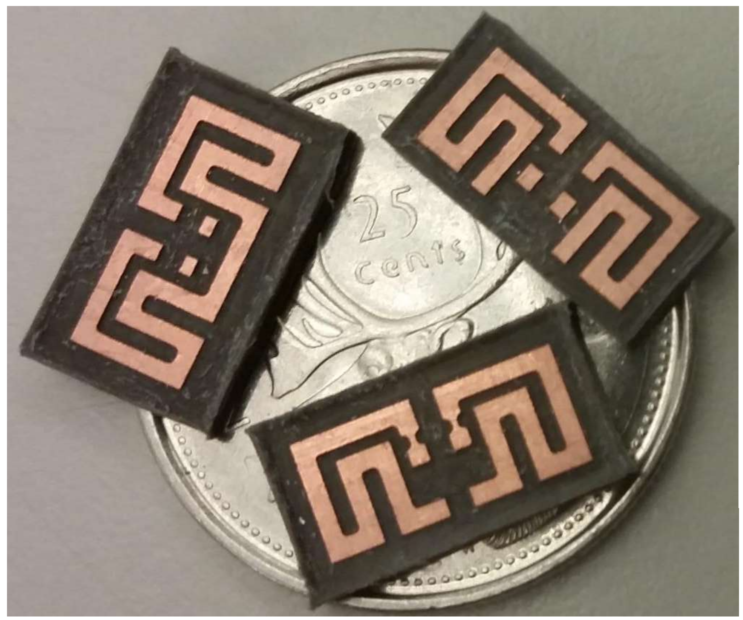


Azimuth



Elevation

Fabricated Prototypes



25 Canadian Cents

Fabricated at the Royal Military College of Canada

Conclusion

A novel electrically small planar dipole antenna was presented in this paper. The proposed antenna exhibits miniature dimensions such that it can easily fit into many small devices operating at 2.45 GHz like smart watches. Three different matching approaches were discussed throughout the paper. The first approach showed a total radiation efficiency and gain of 87.4% and 1.17 dBi respectively. Whereas the second and third approaches showed reduced efficiencies of almost 40% because of the increased current intensity. The dipole antenna was then modelled using the IDM. Very good agreement was seen between the simulated and calculated results which verifies the validity and applicability of such a model.

References

[1] J. Volakis, C. Chen and K. Fujimoto, Small Antennas: Miniaturization Techniques and Applications, New York: McGraw-Hill, 2010.

[2] M. Chiou and S. Chen, "An electrically small planar antenna using complementary split-ring resonators", in Proceedings of International Symposium on Antennas and Propagation (ISAP), Nov. 2012, pp. 1313 - 1316

[3] R.T. Cutshall and R.W. Ziolkowski, "Performance Characteristics of Planar and Three-Dimensional Versions of a Frequency-Agile Electrically Small Antenna", Antennas and Propagation Magazine, Dec. 2014, pp. 53 - 71.

[4] S.R. Best, "Electrically Small Resonant Planar Antennas: Optimizing the quality factor and bandwidth", Antennas and Propagation Magazine, July. 2015, pp. 38 - 47.

[5] P. Turalchuk, I. Munina, M. Derkach, O. Vendik and I. Vendik, "Electrically-small Loop Antennas for RFID Applications", Antennas and Wireless Propagation letters, IEEE, April. 2015.

[6] J.D. Jackson Classical electrodynamics, 3rd Ed. New York: Wiley, 1962.

[7] S. Clauzier and S. Mikki and Y.M.M. Antar, "A Generalized Methodology for Obtaining Antenna Array Surface Current Distributions with Optimum Cross-Correlation Performance for MIMO and Spatial Diversity Applications", Antennas and Wireless Propagation Letters, IEEE , July 2015, vol.14, no.99, pp. 1451 - 1454.

[8] S. Clauzier and S. Mikki and Y.M.M. Antar, "Generalized Superdirective Antenna Arrays", submitted to APS wireless letters.